

Vol. X

MAY, 1923

No. 5.

JOURNAL
OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS



Published monthly, excepting July and August, by the Society,
715 Tremont Temple, Boston, Massachusetts.

Entered as second-class matter, January 15, 1914, at the Post Office at Boston, Mass.,
under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of
October 3, 1917, authorized on July 16, 1918.

Subscription Price, \$4.00 a year (Ten Numbers)
50 Cents a Copy

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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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SYMPOSIUM ON CITY PAVEMENTS.

CAMBRIDGE PAVEMENTS.

By LEWIS M. HASTINGS,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1923.)

THE area of Cambridge, including land and water, is 6.535 sq. mi. There are now on this area 126.07 mi. of ways of various descriptions open for public travel, not including 4.98 miles in the Metropolitan Park roadways. Of these, 109.69 mi. are accepted by the City as public highways, and the rest, or 16.38 mi. are still under private control, very few of these having pavement worthy the name.

CAMBRIDGE PAVEMENT STATISTICS.

Granite block..	5" to 7"	on gravel base	6.684	mi.	189,172	sq. yds.
Granite block..	5" to 7"	on 6" concrete base	3.881	"	79 104	" "
Granite block..	4" recut	on 6" concrete base	1.488	"	41 190	" "
Vitrified brick	4"	on 6" concrete base	2.929	"	57 541	" "
Wood block....	4"	on 6" concrete base	.448	"	16 266	" "
Wood block....	3½"	on 6" concrete base	3.327	"	70 351	" "
Bitulithic.....	2"	mostly macadam base†	18.454	"	386 148	" "
Tar Macadam..	4" to 7"	penetration	35.707	"	562 242	" "
Macadam and gravel	4" to 8"	on soil	34,385	"	335 188	" "

* City Engineer, Cambridge, Massachusetts.

† Concrete Base	71 050	sq. yds.
Granite	9 825	" "
Brick	1 183	" "
Macadam	304 090	" "

386 148 sq. yds.

GRANITE BLOCK.

As may be seen by an examination of the pavement map of the city, the use of granite blocks has been confined very largely to the easterly portion of the city. This is due to the fact that the traffic is here largely business in character and our experience has shown that for heavy traffic of this kind, granite block is the best material to use. When the first granite blocks were placed, forty or fifty years ago, no special base or foundation was prepared upon which to place the blocks, and only sand or gravel was used as a filler. Under the heavy concentration of traffic which has since taken place, serious settlements frequently occurred and the tops became rounded and "turtle backed." This made the granite blocks but little better than the ancient "cobble" or beach stone pavements of the early nineteenth-century days.

With the present practice of using a small well-cut block upon a rigid concrete base with the joints run full of cement grout on bituminous filler, a vast improvement has been made in the desirability of this kind of pavement.

All the paving work, both construction and maintenance, in this city is done by day labor. This method of doing public work, while it has some desirable features, does not usually produce low cost as compared with work done by contract, and also makes it somewhat difficult to obtain reliable figures of maintenance cost.

The cost in 1922 of laying a $4\frac{1}{2}$ -in. new Cape Ann or Rockport granite block on 6-in. concrete base with grouted joints was about \$10.00 per sq. yd. By using old blocks recut the cost was reduced to \$6.00 to \$6.50 per sq. yd.

BRICK.

From 1901 to 1905 Cambridge laid about 25 000 sq. yds. of vitrified brick pavement on a concrete base in a number of streets forty to fifty feet wide and carrying a fairly heavy traffic, all greatly concentrated by railway tracks.

The maintenance cost of these streets has been very small indeed and the pavements are still in serviceable condition after an average of twenty years of service. Other streets have been

paved since with brick, most of them still being in service. Where badly worn some of these have been used as a base for a new bitulithic surface.

WOOD.

The 4-in. wood-block pavement, laid in 1912 and 1913 have given excellent satisfaction. Maintenance has been practically nothing.

The 3½-in. block laid in 1912 to 1915 has not given so good service, especially on wide streets where the paved spaces are wide. After a few years of exposure the preservative seems to evaporate to a certain extent leaving the wood porous and absorptive, with the resulting tendency to expansion and distortion of the pavement.

In my opinion, if the shallow blocks are to be used on any but narrow spaces, the greatest care should be taken to secure a thorough impregnation with the preservative and fixing compounds to prevent undue absorption of moisture, and ample expansion joints should be provided to take up any swelling of the blocks.

BITULITHIC.

As will be seen from the city plan, the "Warrenite" bitulithic type of pavement is popular in Cambridge, about 25 per cent. of the yardage of all the pavement being of this type. It seems well adapted to the requirement of the traffic of many streets in the western section of the city, especially where enough of the old pavement remains to form a good base for the bitulithic surface.

A good example of this is shown on Brattle Street, where in 1919 and 1920, the old surface of tar macadam was scarified and broken up, and the surface then thoroughly rolled to the subgrade on which was placed a 2-in. layer of bitulithic at a total average cost of \$3.13 per sq. yd.

Magazine Street is a case where a heavy tar macadam pavement had become somewhat worn, rough, and out of shape. There the old surface was regulated by trimming and filling to the subgrade, on which the bitulithic was placed for \$1.50 per sq. yd.

Oxford Street was treated in a similar manner. In all these cases the contractor for the pavement gives a guarantee to keep the pavement in repair for five years.

TAR MACADAM.

About 40 per cent. of all the pavements of the city are of the general type called "Tar Macadam,"—that is, the familiar stone macadam impregnated from the surface with hot bituminous compound, about one and one-half gal. per sq. yd. applied in two coats.

For new construction using new cracked stone 4-in. to 6-in. thick, the average cost is about \$1.50 per sq. yd. Applied to an old macadam street with 3½-in. to 4-in. of new stone rolled into the old stone, the cost is about \$1.00 per sq. yd.

Applied to residential and light business streets and given a yearly coat of "Tarvia B" or similar bituminous compound and sand, this type of pavement gives promise of a good length of life and a low annual cost of maintenance.

Probably Harvard Street, from Prospect Street to Massachusetts Avenue at Quincy Square is as good an example of this type of pavement as we have in the city. The traffic here is a mixture of business and pleasure cars, sometimes heavy, and sometimes at night very swift. Most of this was built in 1908, or fifteen years ago, and has never received anything but the surface treatment described above at a cost of about one cent per sq. yd. annually.

NOTES ON ROADWAY SURFACING AND MAINTENANCE TREATMENTS, NEWTON.

BY EDWIN H. ROGERS,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1923.)

THE city of Newton was a pioneer among the cities of this country in the early experimental work relating to the treatment of roads with bituminous preparations, and had established a fixed policy as to such treatment while the majority of other municipalities were still experimenting or had done but little or no work in this line. This city is unique in undoubtedly being the only city of its population or valuation which has no paved streets as this term is usually understood by the general public, which customarily thinks of the word "pavements" as referring to wood block, stone block, cement concrete or else sheet asphalt or similar preparations on a concrete base.

This city has none of these types of pavements, except between tracks and rails of the street railway companies. The reason for this non-use of heavy pavements is that the city's population of some 50 000 is scattered over its eighteen square miles of area in eleven different villages or distinct centres of population, with resulting wide distribution of traffic over a network of more or less moderately traveled thoroughfares connecting these villages and the surrounding municipalities, without concentration of heavy trucking traffic on any single road.

The more heavily travelled ways are surfaced with bituminous macadam averaging $3\frac{1}{2}$ -in. to 4-in. in thickness, constructed by the penetration process, using as a binder bitumen of either tar or asphaltic composition and laid on old macadam or gravel roads as a base. The lighter travelled streets are water-bound macadam or gravel, covered with a blanket coat of asphaltic oil or light tar, and sanded. The city has sufficient mileage of these two types of surfacing so that the cost of construction of

* City Engineer, Newton, Massachusetts.

the former and the maintenance of both types may be taken as representative.

The following table, furnished by courtesy of our street commissioner, shows for a period of years the amounts and costs of new bituminous surfacing, repairs and patching (exclusive of cleaning) of all the city's public ways, and the sprinkling of the larger portion of its streets. The average yardage of the roadways is about $2\frac{1}{2}$ sq. yd. per lineal foot. The city has 153 mi. of public ways, including 43 mi. surfaced with bituminous macadam.

COST OF SURFACING, REPAIRS AND SPRINKLING.

YEAR	BITUMINOUS MACADAM RE-SURFACING		REPAIRING AND PATCHING		SPRINKLING	
	Sq. yds.	Cost per sq. yd.	Miles	Cost per mile	Miles	Cost per mile
1913	49 600	\$0.41	—	—	80	\$275.00
1914	71 105	0.55	144	\$162.00	86	300.00
1915	52 092	0.62	145	179.00	90	348.00
1916	54 657	0.74	145	223.00	90	342.00
1917	42 771	0.98	148	244.00	97	420.00
1918	—	—	148	309.00	112	383.00
1919	14 077	2.13	149	358.00	112	470.00
1920	48 526	2.34	150	277.00	119	492.00
1921	22 166	1.93	153	263.00	121	454.00
1922	28 878	1.56	153	236.00	123	374.00

The method of maintenance on both the penetration roads and those having blanket surfacing is to fill the holes with the usual mixture of stone and bitumen. This patching is continued as needed until further work of that nature is inexpedient when a new pavement is built.

The term "sprinkling" is applied to that treatment the roads receive outside of patching maintenance, and consists usually of not more than one application per year of 45 per cent. asphaltic oil or light tar covered with sand, the two types of material being

used in about equal amounts. The cost of this work is assessed on the abutting property, the rate varying from 3 cents to 5 cents per lineal foot of frontage from year to year.

The city has naturally experimented with practically all the commercial road surfacing materials which it has appeared expedient to try, and at present uses for its penetration work bitumens of asphaltic composition to somewhat greater extent than tar preparations, as it appears that the cost of maintenance of the former is somewhat less, although detailed records are not kept. Non-asphaltic oils were used to some extent in previous years on lateral residential streets, but these materials are not now employed on such work. Light non-asphaltic oils are now used only as dust layers on the paved tracks of the street railways and on such tracks as are not in a grassed reservation but are surfaced with gravel.

The matter of grades on our streets is a problem. In the old water-bound macadam or gravel days the roads were worn down by attrition from iron-tired wheels and horses' hoofs; now that our roads are not so worn down, patching and sprinkling with oil and sand constantly raises them. When they are re-surfaced, the new surfacing is usually thicker than that of the old, for usually a better foundation results from removing but little of the old material, while the saving in cost is an essential consideration. This gradual raising of the roadway grade destroys its proper relation to the sidewalk grade, so we find it advisable in many cases to keep our new sidewalks at a grade of sufficient height above the roadway so that a proper cross-section will result after future repairs or re-surfacing of the roadway is done to a limited extent.

BROOKLINE PAVEMENTS.

By HENRY A. VARNEY,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1923.)

ALTHOUGH Brookline is a strictly residential town, it has, on account of its location in relation to Boston, very heavy traffic through its main streets. It has, however, a very small amount of permanent pavement. By permanent pavement is meant that which is laid on a Portland-cement concrete base. Out of a total of 72 mi. of public streets, only 2.50 mi. are constructed in this manner. Of the above, .32 mi. are 4-in. brick block; .92 mi. 4 to 4½-in. granite blocks; .81 mi. 3½-in. wood block; and .45 mi. "Warrenite" bitulithic.

BRICK PAVEMENT.

The first section of brick pavement, which was the first permanent pavement laid in Brookline, was constructed in 1901. This pavement was laid on a 6-in. concrete base, with a 1-in. dry sand cushion and the joints filled with a Portland-cement grout. Expansion joints were laid, adjacent to the curb, but no transverse expansion joints were provided. This pavement is still in use but, for several years past, has required extensive repairs and will soon have to be entirely rebuilt. A section of the street, on which this pavement was laid, is on a grade of 7½ per cent. and, as it was thought at that time that brick laid on this slope would be too slippery for heavy teaming, this portion was not paved. Consequently the Street Department endeavored to maintain this short section by various other surfaces. A water-bound macadam was used for several years, but this required such constant repairs that finally a bituminous macadam was laid and gave fairly good satisfaction for several years. Finally, however, the traffic became so heavy that it required almost daily patching to keep it passable and, about a year ago, it was decided to lay a

* Town Engineer, Brookline, Massachusetts.

permanent pavement. The improved type, so-called, of Hillside brick block was recommended by the Superintendent of Streets and the Town Engineer. An order was passed for this type of brick to be used, but, when it came to the point of ordering the brick, we were informed that those bricks were not obtainable. We, therefore, used the old Hillside type, which is simply a brick with one edge chamfered. This was laid on a 6-in. concrete base, with a $\frac{1}{2}$ -in. mortar cushion and Portland-cement mortar joints. So far I have heard no complaints as to its being unduly slippery. I should have recommended a granite-block pavement in this location, except that it connects two sections of brick-block pavement and it was principally on account of appearance that we decided on the brick block.

GRANITE BLOCK.

Our granite-block pavement is constructed of the soft New Hampshire granite and laid with Portland-cement mortar joints. It is practically the same type of pavement as laid in Worcester and has given most excellent satisfaction. Generally speaking, the surface of the blocks wears quite smooth, there being no tendency to cobble, the Portland-cement joints being as hard as the granite. Some of this pavement has been laid about thirteen years and, except for isolated blocks, which were evidently imperfect, seems to improve with wear. It is, of course, under certain conditions, rather slippery but, everything considered, it is a very satisfactory pavement. The specifications for this work call for a 6-in. Portland-cement concrete base (the concrete being mixed in the usual manner) or 5 in. of compressed concrete. Practically all the pavement was laid under the compressed concrete specifications. There has been no case where the foundation has failed, although it is undoubtedly a fact that, in many places, there have been substantial settlements underneath the concrete due to improper backfilling of trenches. There have been many openings made in this pavement and I have made careful examination of the edge of the base, as shown in these cuts, and find that the grout has thoroughly penetrated the stone, making a thickness of even more than the amount specified. The blocks

were laid on a dry sand cushion which was specified as being 1 in. in depth. As a matter of fact, I have observed in some openings that the cushion has been as much as $2\frac{1}{2}$ -in. in thickness, but this seems to have had no effect on the wearing qualities of the pavement. I see no advantage in using a mortar cushion in this type of construction.



FIG. 1. BLOW-UP OF GRANITE BLOCK PAVEMENT.
Boylston Street, Brookline, Mass.

A very curious incident occurred in Boylston Street, where this type of pavement has been laid for ten years. During the excessively hot weather of last July, a section, extending from the gutter to the car rail, a distance of about twenty-one ft. "blew up." My attention was called to it as soon as it occurred and I took several pictures and measurements. The situation is shown clearly by the accompanying photograph.

WOOD BLOCK.

Of .81 mi. of wood block, which we have in use, the first section was laid in 1915 on Washington Street, opposite the Town Hall and Public Library. This was laid on the same type of base as used for granite block, with a half-inch Portland-cement mortar cushion and dry sand joints. Preformed-asphalt-expansion joints were laid parallel to the curb, but no transverse expansion joints were used. The wood blocks were $3\frac{1}{2}$ -in. in depth and 3 in. in width. They were of long-leaf southern pine, with a 20-lb. treatment of antiseptic and water-proofing oil, having a specific gravity of 1.12. This pavement has given very good satisfaction and has needed very little in the way of repairs, the principal trouble being that, in some cases, the dry sand in the joints has been washed out. The sections where this occurred were repaired this season with "Tarvia B." This material was poured over the surface and squeegeed into the joints. In some cases, it was necessary to give a second application.

We have two other streets where wood block has been laid. In one case, on Harvard Street, the grade is nearly 4 per cent. We hesitated in recommending wood block on this grade but, after visiting several cities and finding that such material had been used on grades as high as 8 per cent. we decided that there would be no danger in using them in this case. We did, however, take the precaution to chamfer one edge of the block. So far as I know, there has been no complaint from teamsters. The 20-lb. treatment is considered excessively heavy in these days but, from the fact that we have had no blow-ups, I think we were justified in going to the slight additional expense. I may say also that we have had no trouble from bleeding, although the Superintendent of Streets has sanded some sections of Harvard Street and Washington Street, possibly half-a-dozen times since the blocks were laid. In 1916, the car tracks and space between the tracks in Washington Street were paved with wood block under the same specifications as above described. About two years ago, the pavement between the tracks appeared to be settling. Last season there was a depression along a considerable length of the track, in some cases as much as 1 in., and it was

thought that the concrete base had given away, there having been a great amount of underground construction just previous to the laying of the pavement. When the wood blocks were removed, however, and a careful examination made of the base, it was found that, in no case, had the concrete failed.



FIG. 2. WOOD BLOCK PAVEMENT.
Harvard Street, Brookline, Mass.

The cause of the depression was the shifting of the mortar cushion, which had worked to the side and probably, in some cases, had washed away entirely. This would indicate that the mortar cushion was not properly moistened when the blocks were laid.

BITULITHIC.

Last season a portion of one of our main streets was paved with "Warrenite" bitulithic. This pavement was laid on a 5-in. concrete base. This concrete was mixed by the usual method. As there were car tracks in the center of the street, two rows of wood blocks were laid adjacent to and parallel with the outer

rail. The space between the rails and between the tracks had been previously paved with wood blocks.

In addition to the pavements above described, we have 2.25 miles of "Warrenite" bitulithic laid on a macadam or telford base. The section of Beacon Street, extending from Park Street to Washington Square was laid in this manner and, so far, has given entire satisfaction, the only criticism being that at times it is rather slippery, but no more so than many bituminous macadam surfaces. The base for this work is really telford rather than macadam, as Beacon Street was originally constructed in 1887 with a very heavy telford base. In laying the bitulithic top, the surface was scarified and the old bituminous material removed. Very little new stone was added, however, there being sufficient small stone for the adjustment of the subgrade. The Riverdale Parkway, for practically its entire length on the Brookline side, is laid in the same manner. In this case also there was a heavy stone foundation as practically the entire length of this drive is constructed on a fill and considerable settlement took place after the original construction and the settlements were made up, from year to year, with either crushed stone or ledge chips. I would not recommend this type of construction for streets where there has been much underground construction, particularly if trenches of any depth have been excavated within a period of three or four years, but, in situations like those above described, it is quite satisfactory and can be laid with a saving in cost.

HISTORY OF NEW BEDFORD PAVEMENTS.

BY GEORGE H. NYE,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1923.)

As I understand the object of the group of papers for this meeting, it is the desire to obtain the experience of the cities in different sections of the state with regard to certain types of pavement, particularly as to the satisfaction they have given in use, their durability, ease of maintenance, and relative cost. The experience in different cities will of course vary greatly as influenced by local conditions, but this exchange of the individual experience of the engineers should prove helpful and be of mutual benefit.

With this point in view, I submit practically the history of pavements used in New Bedford and the results obtained from each. I have not attempted to explain technical methods of construction or to enter into the details of cost.

The soil of New Bedford is mostly a light, sandy loam on hard pan, the grades are moderate, few being above 5 per cent. and in many places the soil is saturated with water. Our average winter temperature is in the neighborhood of 32 degrees, resulting in the rapid melting of snow and frequent freezing and thawing during the winter. In the spring, with frost coming out, the old, unimproved roads were a mass of mud, water and ruts. This is poor foundation for improved pavements and requires considerable sub-soil drainage.

The first pavements laid many years ago, were large, round cobblestones, of which there is a plentiful local supply. These were laid on a bed of three or four inches of sand. Of course, such a surface was never satisfactory, and required constant repair owing to the stones settling and forming ruts.

The next pavement used was water-bound macadam, first laid about 1880, and the use of which was discontinued about

* City Engineer, New Bedford, Massachusetts.

1920. There are, however, many streets of secondary importance on which this surface is now in use. Where the surface is still of value we are now protecting it with a surface treatment of asphaltic oil and sand. Wherever it requires major repairs, however, we are replacing it with other pavements.

These macadam streets gave fairly good satisfaction at first. Our local stone is a rather brittle granite and later being broken and laid, it crumbled to some extent under the roller and gave a very close bond. These streets, however, were dusty and for years were watered regularly to lay the dust. Later light oil or dust layer was used, but this was expensive and never proved satisfactory. With the advent of the rapidly-moving auto with rubber tires, these pavements became impossible. The wheels pulled out the binder and the roads ravelled rapidly into ruts and holes.

About 1900 we adopted much better and more permanent types of pavements for our principal streets. On the heavy-teaming streets in the industrial sections we adopted a granite-block pavement laid on a 4-in. base of cement concrete with two inches of sand filler and 7-in. granite block grouted with Portland cement and sand.

We later changed this construction to a 4-in. cement concrete base, laid on a carefully prepared and thoroughly rolled sub-grade, 1-in. sand cushion, and 5-in. paving blocks grouted with Portland cement or pitch filler.

These streets are proving satisfactory, with one exception, and we have had no cases of base failure except where directly traceable to faulty backfill of trenches, stop boxes, etc. These pavements have been constructed with locally-cut blocks, and as our local stone is a brittle granite with poorly defined cleavage planes, they were rough when first laid, and in use small depressions quickly made their appearance, due to the spawling off of the brittle stone as if broken by hammers. This resulted in depressions in which puddles formed and from which mud and water were splashed on pedestrians and on buildings. This has resulted in much complaint from the public and in some cases we have covered these surfaces with a 1-in. layer of bituminous concrete and asbestos, with satisfactory results. You will all

recognize the difficulty, however, of raising the surface of the street this amount, especially those in which there are car tracks.

In a few cases we have used a fine-textured, smooth-breaking granite block, bought outside the city, and have had splendid results. However, you all know the difficulty encountered in purchasing a commodity where the principal cost is for labor outside the city, against the demand for expending public money to furnish employment for local labor.

For this reason, we have practically abandoned the use of this type of pavement except on steep grades, where its inherent roughness is a decided advantage, and from which the water readily drains off.

For our standard pavement for primary streets, we have adopted bituminous macadam. In this we have taken one very radical step, for we are using it with perfect satisfaction on streets having only the very heaviest of truck traffic.

These pavements were first laid on a bituminous concrete base, later on a 6-in. base of Portland-cement concrete, and at the present time on a 6-in., rolled-stone base, or, where it is still available, on the old macadam. This latter results in a great economy.

Some of these pavements have been in use twenty years, with only minor repairs, and are still in fine condition. We have had no base failures under the heaviest loads except as stated above in the case of stone pavements.

The surface is smooth and quiet and has proved very popular with the public.

For our secondary residential streets, we are using penetration macadam, laid from curb to curb without gutters. We use a stone of the general quality of trap rock and found in one place locally. We penetrate this with about two gallons of tar to the square yard, cover with screenings, and subject it to use for about one year; then sweep it thoroughly and treat it with about one-fourth gallon of asphaltic oil, applied hot and covered with sand or chips.

These streets have proved very satisfactory, but it is too soon to determine what the length of their life will be. Wherever we have opened them, we have found them in fine condition, and

the tar practically in the same condition as first laid. Two of our most traveled main streets were thus constructed in 1916 and are still in first class condition, having had only two surface treatments of asphaltic oil during that time.

We have never used concrete for a road surface as my observation of such roads in this locality has convinced me that this material is wholly unsuited for use with our climatic and soil conditions.

We have a small amount of brick pavement which has proved satisfactory, but have not continued its use on account of our preference for bituminous streets. The same is true of wood block where a much more expensive pavement is no more satisfactory than the bituminous surface.

In the matter of cost, we have found that the stone block pavements have cost about \$8 a sq. yd., the bituminous concrete about \$4 a sq. yd., and the penetration macadam about \$2 a sq. yd.

We have practically standardized on bituminous concrete for our primary streets and penetration macadam for our secondary streets, and from the comments on the streets of New Bedford by visitors, we believe we have chosen wisely.

FITCHBURG PAVEMENTS.

BY DAVID A. HARTWELL,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1923.)

THERE are at present in the city of Fitchburg about one hundred and forty-seven miles of accepted streets and roads. So far as the wearing surface is considered they could be classified approximately as follows: earth and gravel, 114.5 mi.; bituminous macadam (penetration) 23.6 mi.; granite block paving 7.8 mi.; wood block paving 0.65 mi.; and cobble, brick, bicomac and asphalt block 0.69 mi.

Bituminous macadam with six inches of trap rock on a good gravel base has given such excellent results under years of service that this type may well be considered as standardized in Fitchburg for residential streets and main arteries leading to surrounding towns. Nearly a mile of this type of road is laid each year. The cost per mile with a width of 18 ft. varies from \$22 000 to \$25 000 depending on length of haul, cost of material and local conditions. In 1921 macadam of this type was laid in the main road between Fitchburg and Ashburnham for a distance of 5 372 ft. at a cost of \$2.36 a sq. yd. This cost included 43 cents a yard for excavating and sub-grade; 17 cents for culverts, guard railing and miscellaneous work, and \$1.76 for material and labor for macadam. The average length of haul on this job was $1\frac{1}{2}$ mi.

Fitchburg is built around quite an extensive hill of granite and it was to be expected when a pavement was needed to sustain heavy traffic that granite blocks would be used. All such paving until within about eight years was laid on a gravel base with sand, pebble and pitch, or cement grout filler for joints. Twenty-five years ago such paving gave a good degree of satisfaction. It was not expensive and was a great improvement over previous conditions. At present it is our practice to lay all granite blocks on a 6-inch cement concrete base and fill the joints with cement

* Commissioner of Public Works and City Engineer, Fitchburg, Massachusetts.

grout. In 1921 new work of this type amounting to 7 855 sq. yds. was laid in one street at a cost of \$5.39 a yard. The cost per sq. yd. was as follows: excavation and sub-grade 72 cents; cement concrete base \$1.16; granite blocks \$2.34; laying, ramming and grouting 96 cents; miscellaneous 21 cents. The blocks averaged 28.7 per yd. The labor cost was \$1.70 a sq. yd. or $31\frac{1}{2}$ per cent. of the total cost.

In 1922 a beginning was made on relaying our old granite block paving. About one-half a mile on River Street was taken up, the blocks recut and laid on a 6-inch concrete base and the joints filled with cement grout. This street has a double-track street railway. This work cost \$3.79 a sq. yd.

Wood-block paving has been laid in a number of streets, some of which have very heavy traffic. The first of this type was laid in 1913 and has had about ten years of service. The earlier work of this kind has had extensive repairs and more are needed. It is very slippery when wet and during frosty weather, causing horses to fall and autos to skid. It requires early and frequent repairs when laid in streets having railway tracks. Paving of this type, after being in service six to eight years has buckled. Our experience has been that in first cost it is higher than granite block, requires extensive repairs within 10 years, and is not as satisfactory to the users of the street.

We have one street laid with asphalt blocks on a concrete base where there is a moderately heavy traffic. This has been laid six years, has given good satisfaction without any repairs, and at present there is no indication that any repairs will be needed for some years.

Brick has been used a little but it has not been very satisfactory and there is no local sentiment favorable to it.

Asphalt has not been tried, and probably with our satisfactory work along penetration lines there will be no desire to lay a more expensive though more durable type.

Without any question the presence of railway tracks in a street is the great difficulty in the maintenance of a satisfactory pavement. All the different classes of pavement in Fitchburg are in streets having a railway, and experience has shown that granite block paving is the best under such conditions.

All permits to excavate issued to any person or corporation have as a condition that the permanent replacement of the paving shall be made by the city forces at the expense of the permittee. Excavation in any street is a decided injury to the paving and no matter how well it may be replaced the injurious effect cannot be wholly obviated. Our experience has been that the injury to granite block paving is the least noticeable.

All cleaning of streets is done by patrol men or by a pick-up sweeper. All dust laying is done with oil. No sprinkling or flushing has been done for four years, the only water on our streets has been from rain. No difficulty has been experienced in keeping all types of paving clean, and no complaints have been made by merchants relative to dust.

While I cannot give any definite figures as to cost of maintenance still I will say that new granite-block paving costs no more than some other types, and the maintenance is practically nothing for a period of many years, which cannot be said of other types.

WORCESTER PAVEMENTS.

BY J. C. BLAKE.*

(Presented February 21, 1923.)

It may be that I am violating all the ethics and standards of engineering in presenting this paper, but facts are facts and the proofs are in existence in my own city and can be shown to any one who desires to inspect them. We hear a great deal of engineering talk about foundations and sub-grade preparation for pavements, but in my city there is but one piece of pavement which has ever been given sub-base construction treatment and that was an asphaltic concrete pavement and it cost probably more than any equal area of grouted-granite-block pavement would have cost at that time.

Owing to the time limit that has been imposed upon me my remarks must, of necessity, be brief so that I will not touch on all the different types of pavements which we have constructed in our city, but will confine myself to four. Our city has the usual New England sub-soil conditions, our valleys many of them showing gravel deposits and our hills being of hardpan. This hardpan of course is a very difficult sub-soil in the spring months and also during the summer rains.

I will pause for an instant to remark that one of our greatest life savers has been the application of light road oils to hillside surfaces which previous to this application we would usually find in the valley below after heavy thunder showers but which, subsequent to its application, would usually shed any quick rain thereby saving us many thousands of dollars of street maintenance each year. It is, however, more desirable to retain these surfaces in a more permanent manner and consequently the idea was introduced of a 4-in. cobble stone penetration of either tar or asphalt. This pavement was applied direct to the hardpan surface. We have many miles of it in Worcester. It is the only thing that we have ever found which would cheaply and success-

* Street Commissioner, Worcester, Massachusetts.

fully tack down the hillside street and not allow it to run away into the valley in the springtime and under heavy downpours continuing for a long period. The stone we use brings smiles to the faces of engineers who look over our crushed stone piles. This stone is manufactured in the winter time, providing a great amount of winter labor, stacked in piles and handled by steam shovel into carts or auto trucks in the spring. The crusher jaws are open, much wider than is usual, in this manner allowing the damp gravel to go through without choking, and the product is usually what would be considered a 3-in stone, many of the cobbles passing through as large as the size of my fist. I believe that the entire success of penetration work depends on a large size stone being used as the first course, allowing a penetration which goes clear to the bottom of the stones and makes on final completion a solid pavement from top to bottom. That there has been no necessity for any sub-grade preparation is indicated by many of these streets which are today six to twelve years old and are still showing no signs of final disintegration and no deterioration of riding quality.

The second type of pavement in use is both the mixed and penetration method of cement concrete.

No cement concrete pavement constructed in the city of Worcester has ever had any preparation of sub-grade other than the natural sub-soil of the street on which it was placed. Many of these are on hardpan. Some are at least fifteen years old. Only one of these pavements has been replaced up to the present time, that being one of the first, constructed at a time when little was known of the penetration method of cement concrete construction, and, due to excessive roller action, which is now omitted in such construction, more than to action of frost or traffic, this street got into such shape that it was spiked up, rolled and covered with an asphalt concrete top. The others are in existence today, and giving excellent service. Last year the city constructed a section of 8-in. reinforced-concrete pavement on one of its heaviest-travelled streets—this was laid on natural soil over a section of muck swamp on which a sewer once settled and broke apart. Naturally I realized that this is against all precedent of construction on the Massachusetts state highway work, but I

have been given to understand that in New York state highway work construction less than 10 per cent. of their state highways are constructed on anything other than the natural sub-soil occurring in the section where the road is to be constructed.

In the one case as above indicated we have used a plastic style of pavement on the natural sub-soil, in the other case we have used a rigid type of pavement on the natural sub-soil, and I



FIG. 3. GRANITE BLOCK PAVEMENT.
Commercial Street, Worcester, Mass.

cannot see that in either case over a long period of years through which these highways have been constructed that the frost action has been of any material damage to the pavement. Naturally if it would affect a rigid pavement like cement concrete it would also affect a rigid pavement like granite block.

The city of Worcester possesses the best cement-grouted granite-block pavement in the United States. This statement I will not qualify and it is recognized by engineers throughout the country. No single piece of this pavement has ever received any sub-grade treatment and it is all deposited on the natural sub-soil whether it be a grouted granite-block pavement on a concrete

base or on sand cushion on a natural sub-soil. It may be that you are going to question this last statement, due to the fact that some of our pavements are deep granite blocks cement grouted laid on a sand cushion without a cement concrete base, but the cushion used was simply for the purpose of bedding the blocks for ramming and not as a provision for sub-grade construction.

I have in mind a new style of pavement which I wish to try out in connection with these deep blocks which will be a novelty in construction which I do not think has ever before been attempted. The process will be as follows:

On a sub-soil properly graded will be placed the thickness desired of cement concrete mixed in the following proportions: One part cement, 2 parts sand, $3\frac{1}{2}$ parts of $\frac{1}{2}$ inch to inch crushed stone or clean screened pebbles. These will be mixed moist or damp. On this the granite blocks will be bedded and immediately rammed. Following this the granite blocks will be wet down previous to the application of a 1 to 1 cement grout. The application of the water and the application of the wet grout will sufficiently moisten the concrete base course as it is a well known fact that in general practice concrete is mixed too wet and that an application of as little as 15 per cent. too much water will decrease the strength of the concrete from 30 to 50 per cent. The grouting shall immediately follow the ramming and will complete a monolithic pavement making it one unit from top to bottom which I am confident will stand heavier traffic, if the old style 6 to 7-in. block is used, than any modern type of granite block pavement constructed today, as it will form a monolithic arch across this street which no present day traffic will break down; there will be no joint which would not bond as there is in granite-block-paved streets where the base is constructed and allowed to set, followed by either cement mortar or sand cushion and grouted, where there is a line of cleavage and the pavement is not monolithic.

We have also our own asphalt plant and have constructed many successful asphaltic concrete tops for worn out macadam streets and also tops for cement concrete base. I may state also that all of these pavements constructed on concrete base have been constructed on a natural sub-soil and are giving excellent service.

HIGHWAY TRAFFIC IN MASSACHUSETTS SINCE 1909.

The following figures illustrate the phenomenal growth of traffic in Massachusetts since 1909.

Four traffic counts have been made in 1909, 1912, 1915 and 1918, respectively. The counts were taken from 7 A.M. to 9 P.M. The observation stations were on the main through roads and so selected as to be away from the influence of merely local village traffic.

In 1909 the census was taken at 238 stations, in 1912 at 156 stations, in 1915 at 192 stations, and in 1918 at 57 stations. The counts were made for seven consecutive days in August and again in October. At a few important points the count was made at night, covering the entire 24 hours.

The classification of vehicles was as follows: 1-horse vehicle, light; 1-horse vehicle, heavy; 2 or more horses, heavy; motor truck or bus, small; motor truck or bus, 1 ton or more; automobile.

Based upon average counts at 44 stations on main lines the increase in motor traffic from 1909 to 1918 was 661 per cent. with a total decrease of horse-drawn vehicles of $62\frac{1}{2}$ per cent, and a net total gain of all vehicles of 243 per cent. It is noted that in 1909 there were practically no trucks; in 1912, 17; in 1915, 45; and in 1918 there was an average of 75 recorded daily. In 1909 horse-drawn vehicles constituted 57 per cent. of all the traffic; in 1918, 6 per cent. of the traffic. During the years 1916-1919 it is noted that motor traffic had increased at the rate of 22 per cent. a year.

In 1919 traffic counts were made at 107 stations, the following tabulation being a comparison of traffic for 1917, 1918 and 1919:

	1917.	1918.	1919.
Average daily traffic....	339	260	337
Motor-driven.....	86.1 per cent.	78.5 per cent.	90.3 per cent.
Horse-drawn.....	13.9 per cent.	21.5 per cent.	9.7 per cent.
Local traffic.....	93.5 per cent.	78.1 per cent.	76.6 per cent.
Through traffic.....	6.5 per cent.	21.9 per cent.	23.4 per cent.

REPAIR AND MAINTENANCE OF BOSTON STREET SURFACES.

BY EDGAR S. DORR,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented February 21, 1923.)

THE phase of the paving problems upon which I shall make very brief remarks is that of repair or maintenance of street surface in spite of the many openings which are necessary.

This problem has never been satisfactorily solved in the city of Boston, although it was the governing consideration in the consolidation of the separate departments into one large department, a change which first took place in 1891, only thirty-two years ago.

Our non-success has been due to a number of causes, but principally to two causes, unsuitable organization, and adherence to an assumption which has been, and now is, almost universal, but which I now believe to be fallacious, namely, that a permanent repair cannot be made until a long time has been allowed for the back-fill to settle, not less than six months.

There is no question about the importance of having the back-fill thoroughly consolidated, it is the most important factor in the whole problem, the question is as to how much time is necessary to allow for it. If that time is long, sometimes extending over into the following year, it is difficult to keep track of the great number of openings and follow up and get the work properly completed.

The magnitude of the job may be judged by the facts that about 13 000 permits for openings are issued annually, and the aggregate length of the openings runs from 105 to 150 linear miles.

I think that every one will agree that the desideratum is to have the permanent repair of the pavement made at once upon the completion of the work that made the opening necessary, if it be feasible to do so.

* Planning Engineer, Public Works Department, Boston.

It is feasible, because it is being done in New York City.

The department in New York demands the immediate replacment of the pavement in permanent shape upon the completion of the work for which the excavation was made, no temporary pavement is allowed. The department has in its hands a guarantee fund, deposited and kept good by each public service corporation, which fund the department may use to defray the



FIG. 4. INGERSOLL-RAND PORTABLE COMPRESSOR PLANT.

expense of making the permanent pavement good, if there is any hesitation on the part of the corporation in obeying an order to do so.

The method to be followed in making an immediate permanent repair is not specified by the city; it is evident that it is up to the corporation to find a practicable method because it does not pay to lay down permanent pavement several times.

The problem, of course, was to effect the immediate and complete consolidation of the back-fill. There are two ways of doing it, by puddling and by ramming. Puddling is efficient

provided an abundance of water is available, but there are vexatious difficulties about getting it without injury to hydrants, and in conveying the water across streets crowded with traffic. Ramming is the ready practicable way, especially with a multitude of small openings. Hand-ramming cannot be depended upon because it is impossible to tell whether or not the workman



FIG. 5. POWER RAMMING IN TRENCH BEFORE REPLACING PAVING BLOCKS.

is putting any force into his blows; by a process of elimination therefore the New York companies adopted power ramming.

The power is furnished by a little portable power plant, consisting of a gasoline engine running an air compressor, which furnishes the compressed air to the individual "guns" so-called, which are furnished with the rammer, chisel, bull point or whatever tool is desired.

In this city the ordinances unfortunately do not support the commissioner of public works as they do in New York, and if the plan fails here it will be due to that fact. However, something can be done and has been done under unfavorable ordinances. The New York plan has been put up to the corporations, and one company, the Gas Co., has responded finely and has already bought and is using two of these outfits, others will probably follow, the city is buying two, and the speaker believes that this year will see it demonstrated that Boston can protect its permanent pavements as well as New York.

JOINT DISCUSSION.

EDWARD S. LARNED.* I should like to ask Mr. Blake to give his idea how, with the suggested monolithic pavement it will be possible to cut a narrow trench and get out a clean section of pavement without doing injury to the pavement immediately adjacent to the cut?

MR. BLAKE. Of course you are going to shatter a little on either side, but we break it out like any other pavement. I see no reason why there should be trouble. It would be done just like any granite block. You must shatter the blocks next and chisel it out.

FRANK A. MARSTON.† The Chairman of the Brick Paving Committee of the American Society of Municipal Improvements has put up a question on which a discussion would be of benefit.

"Do you prefer a mixture of one part Portland cement and one part sand, or one part Portland cement and two parts sand, to be used as filler for brick pavements? Which? Why?"

Perhaps Mr. Varney can answer this question.

MR. VARNEY. I prefer a grout mixed in the proportions of one part sand to one part cement, for the reason that the joint is more likely to be completely filled than when a larger proportion of sand is used.

MR. LARNED. I would like to ask the opinion as to the relative merits or necessity of using a mortar cushion instead of a clear sand cushion on brick pavement.

* Civil Engineer and Specialist in Cement, Sand and Concrete, Boston.

† Of Metcalf & Eddy, Consulting Engineers, Boston.

MR. VARNEY. The experience I have had with the shifting of wooden blocks would indicate that it is wiser to use a mortar cushion, the dry sand being liable to displacement, under certain conditions.

MR. HASTINGS. I think it has been a not uncommon experience that the sand cushion may become a rather dangerous factor under a brick pavement.

Under some conditions the sand is readily shifted from one place to another, causing a movement and inequalities in the surface of the pavement. The tendency has been for some years now, to reduce the thickness of the sand cushion to a minimum, or even dispense with it altogether and make the whole work a monolithic structure.

The concrete base is struck off to a true subgrade and the bricks laid upon it before the concrete is set, the whole is then lightly rolled or rammed and joints filled with cement grout.

Square-cornered, wire-cut brick only are used for this purpose.

The City of Boston paved a portion of Arlington Street, near St. James Avenue, a few years ago with a brick pavement of this general type.

Sometimes a thin collar-joint of dry sand and cement is used as a cushion and the joints between the brick are run full of a bituminous compound making a "semi-monolithic" pavement. This type is claimed to be less noisy under traffic than the first type referred to.

MR. NYE. Brick is little used in this section and there is but very little in New Bedford. There is one piece on the Fair Haven Bridge, laid with cement filler 1 to 1. The grouting broke up as soon as traffic went on it. The bricks have moved under this traffic and the joints have filled with dust and dirt, yet the bricks have been in use now twenty years and are still in fair condition and giving good service. In another part of the bridge we are faced with the matter of new rail construction. This will be improved construction, the rails being laid on steel ties laid in cement concrete with one brick header outside of the rail and sixteen feet of brick surface between the rails. This will be laid monolithic on the fresh concrete and the joints filled with pitch filler, to give elasticity. I don't know whether this is

good construction or not, but I had decided to do it and if I am wrong I would like to know it before I put it down.

MR. MARSH. I could show Mr. Nye some granite blocks laid between car tracks on one of our main lines. The joints are filled with pitch filler. There seems to be some sort of hydraulic pressure from underneath which drives the blocks up 1 to 1½ in. at a time. Fortunately we grouted that part of the pavement from the rail to the curb, so we take the blocks up and put in pitch and put them back. Somehow the working of the car tracks forces out the blocks. We get a sort of hydraulic pressure, particularly on a hot day.

MR. NYE. I did that very thing on a 5 per cent. grade on car tracks last summer, — granite blocks on a concrete base with pitch filler — and it has proved absolutely satisfactory. Possibly it was a heavier filler. It was quite heavy so that when it hardened even in summer it remained a hard solid substance.

MR. MARSH. We have had about five different kinds of filler and have had an expert out who tried different mixes, and it all did the same thing.

MR. MARSTON. I guess there is some difference in the value of "N" in that hydraulic formula.

W. L. FEWSMITH.* I cut from the Boston Post of February 2, an article upon the use of rubber pavement for Boston and its feasibility. The information I am looking for is whether any one does consider it feasible. Has any man who knows pavements ever heard of "rubber" pavement?

MR. DORR. I can give as much information as any one on that, and that isn't very much. A proposition was presented to the Mayor and finally handed down the line to me to investigate. I couldn't pass it any further, and it struck me as it does all of you as something rather comical. But when I looked into it that wasn't the case. I don't say it can be done within reasonable limits of cost, but it is more nearly practicable than I supposed. I found first that rubber pavements had been laid in London since 1876 at various intervals, and the statement was made that some of them have lasted thirty years. Now if a pavement will last thirty years you can pay considerable per square yard for

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it, because the cost per year will figure down so far. My only information has come from proponents of rubber roads. I can't think how to check it unless I go over and look at it myself. Various forms of block and slab pavement have been brought in and submitted for inspection, and they are astonishingly good. I begin to be almost an advocate myself of rubber pavement, in spite of the fact the humorists are having a lot of fun with it. I am pretty nearly ready to make the prediction that rubber roads are coming in some localities, such as around hospitals and residential districts where silence is desired and where roads which will not be slippery, are wanted. The only other noiseless pavements are wood block and asphalt, and they are slippery. Every time we plan to lay a wood pavement a representative of the Master Teamsters comes in and presents a protest. The protest is put on file and we go ahead and lay the pavement. Even if rubber costs more, if the life is anything like what is claimed for it, it might well be worth what they claim.

MR. FEWSMITH. I happen to know that the Sultan of Siam who is very fond of quiet has had his palace surrounded for a distance of half a mile with pure rubber paving. It produces absolute silence. I have heard it suggested that it would be of great advantage on a structural steel bridge, for the reason that it would eliminate to some degree the vibration, which is detrimental to steel structures.

MR. DORR. I might add that it is being considered in the Harvard Bridge problem. We may find a good application there. The bridge is strong enough but it is not rigid enough to stand the vibration. The vibration is excessive and will ultimately ruin the bridge. Now any pavement which would minimize the vibration might obviate the necessity of spending quite large sums of money, from four to seven million dollars. Even at the lowest estimate, — four million dollars — the interest would be \$200 000 a year. The cost of such paving, from the best estimates I can get would be less than two years' interest on the sum of four million dollars. If rubber pavement were put down on Harvard Bridge and prevented vibration and lasted over two years, we would be ahead of the game from that time until the pavement wore out.

JOHN W. HAHN.* (*by letter.*) I am glad to give some information regarding the laying of the vitrified-shale, paving-brick block, which was put down four or five years ago on Arlington Street, running from Boylston Street to St. James Avenue.

I furnished these brick blocks and helped to supervise the laying of same, in conjunction with William C. Perkins, Chief Engineer of the Eastern Paving Brick Manufacturers Association. This pavement consisted of what is called a "wire-cut lug, vitrified-shale block," the lug being manufactured in one process of cutting, leaving a rough side which offers a better foothold for grout or the asphalt filler, cement, etc., used. In this instance a cement filler was used. The paving-brick blocks were $8\frac{1}{2}$ -in. $\times$ $3\frac{1}{2}$ -in. surface $\times$ 4 in. deep, weighing 10 lb. apiece, 40 to the sq. yd. I believe a 5-in. base was used, the regulation depth concrete base used by the city of Boston, then 1-in. cement-sand, (1 to 3) applied dry. After this cement-sand mixture was leveled off the brick blocks were laid and a hose applied to set up the cement-sand mixture. After allowing a reasonable length of time for this setting up the brick blocks were thoroughly grouted with a cement mixture (1 to 1).

On account of this strong bond, a 3-in. block (weighing about 7 lb. apiece, same surface dimensions as the 4-in. depth block,) would be sufficient on many streets where there is not much heavy traffic and they will give good service. The city of Auburn, Maine, used 1 000 000 and Pittsfield, Mass., about 2 000 000 3-in. wire-cut lug block. Auburn used a 3-in. concrete base and a 1-in. cement-sand bed.

In paving-brick circles, a good practice is to use a fiber block $8\frac{1}{2}$ -in. $\times$ 4-in. wearing surface, $\times$ 3 in. deep, laid with an asphalt filler, of which millions are being used in the West.

J. P. SNOW.† (*by letter.*) A type of pavement that I have not heard discussed to an adequate extent, is straight cement concrete for the wearing surface. We know that thousands of miles of highways, through rural districts, and streets in villages and cities, have been built in the western part of the country. Why it is not more general in the East, I do not understand. Our

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† Consulting Engineer, 18 Tremont Street, Boston.

neighboring city, Peabody, has a considerable amount of this type, which is apparently giving good service. The secret of success with concrete seems to be plenty of well-placed asphalt expansion joints, coupled with a good grade of concrete containing a durable kind of aggregate. Of course the foundation must be proof against heaving by frost.

I have had quite a lot of experience with granite block and bricks on plank bridge floors, and in answer to the question as to a thick or thin cushion of sand underneath, I would say the thinner the cushion the better, if all spaces below the blocks are filled. I prefer a thin mortar for bedding each block as set, although grouting blocks laid dry will do the work, if light ramming is done while the grout is being poured.

Another type of bridge-floor paving that I want to mention has been used with very satisfactory results in central New Hampshire. It is tar concrete from 2 to $2\frac{1}{2}$ -in. thick on plank. If of the right consistency it seems to hold all right, whether it is edged with substantial curbs or merely thinned out at edges of roadway. This type of paving was used twenty years ago, when all vehicles were horse drawn and had steel tires. Rubber tired traffic is much easier on it. I submit that if the maintenance of Harvard Bridge, which has been mentioned, was on my hands I would cover one-half the roadway for a hundred feet with this material and see what would happen. The paving, however, must not be depended upon to replace spikes in the planking nor lateral bracing in the bridge structure.

ACTIVITIES OF THE FEDERATED AMERICAN ENGINEERING SOCIETIES.

ENGINEERS TO AID PRESIDENT IN PLAN FOR GOVERNMENT REORGANIZATION.

WHEN President Harding reported to Congress that his Cabinet had agreed upon a plan for Government Reorganization, the Federated American Engineering Societies, which had been in close touch with the members of the Cabinet, in regard to the plan, appointed a committee to aid further in the work. The committee will be known as the "Committee on Government Reorganization as It Relates to Engineering Matters," and will be headed by J. Parke Channing, with Philip N. Moore as Vice-Chairman.

In announcing the process of forming a well-rounded committee of representative engineers and the proposed plan of work, Chairman Channing issued the following statement:

"The proposed Reorganization of the Executive Departments of the United States Government is a direct outcome of the work of American engineers to create a Department of Public Works as carried on by the former Engineering Council, the National Public Works Department Association and American Engineering Council.

"The advantages and economies of such a department were so evident that public-spirited citizens felt it should be carried to its logical conclusion and a complete reorganization of all the executive departments be made. Their feeling resulted in preparing the proposed reorganization as set forth in Senate Document No. 302, 67th Congress, 4th Session.

"As a whole, engineers favor the proposed plan of reorganization of the Executive Departments as it applies to engineering activities, upon which activities they feel themselves competent to pass.

"While the proposed plan is not in every detail that advocated by the National Public Works Department Association, engineers feel that the scheme is a great step in advance and will advocate it with perhaps certain modifications."

In commenting upon the progress of the campaign for Government Reorganization, Mr. Philip N. Moore, Vice-Chairman of the committee remarks as follows:

"The item in the report which engineers welcome with most pleasure is the establishment of a National Division of Public Works as one of the two divisions of the Department of the Interior. The proposed plan covers almost every point which has been urged by the Federated American Engineering Societies, its predecessor, the Engineering Council of war days, and the National Department of Public Works Association. This is a recognition in the very highest centers of the correctness of the engineers' recommendations and a justification of their campaign initiated more than four years ago.

"The practical agreement of the President and the Cabinet upon the plan is most satisfactory to engineers. In fact, we believe but for the vigorous campaign started in 1919, it is questionable whether the necessity for reorganization of Government departments would have been noted at all by those in authority.

"While it is incapable of accurate proof, internal evidence points to the fact that the engineers' agitation called attention to the many duplications in Government service and that this was the inciting element which focused the efforts of legislators and the President upon the subject. We believe we can claim it as one of the results of engineering organizations."

The committee which is designed to be permanent and which represents many National and local engineering societies in all sections of the country, has among its membership two prominent engineers, members of the Boston Society of Engineers, namely, Irving E. Moulthrop and Col. Chas. R. Gow.

Mr. Channing, already pushing the work of his committee, is a prominent mining engineer, member of the American Institute of Mining and Metallurgical Engineers, Chairman of the Hoover Committee on Elimination of Waste in Industry, Vice-President of the New York Committee on Public Works and is now Vice-President of the American Engineering Council. Mr. Moore is another Vice-President of the American Engineering Council, a Past President of the American Institute of Mining and Metallurgical Engineers, former chairman of the War Minerals Relief Commission and has always been prominent and active in Government reorganization matters.

DISCUSSION.

THE AMOSKEAG MANUFACTURING COMPANY HYDRO-ELECTRIC
DEVELOPMENT.*

By C. H. PIERCE,† MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.
(*By letter.*)

While enjoying Mr. Safford's pictures and description of the magnificent new hydro-electric development on the Merrimack River at Manchester, N. H., an engineer can not fail to be impressed by the strength and stability evidenced by every feature of the design. Whenever we investigate the section of any dam with which Mr. Safford has been connected in design or construction we find this same idea of "Safety first" as the paramount consideration. The new Amoskeag dam and power house stand as monumental tributes to the science of hydro-electric design, and in view of the size and importance of this development it would be highly desirable to have the cost data made available in order that we may know the value which an up-to-date business corporation places upon its water power, and also that other companies owning water-power sites may be encouraged to build wisely and for all time. Will not Mr. Safford give us in a supplementary paper some general information as to the cost of the completed structure? Data regarding unit costs of individual items, taking such items as appear in the list of material and equipment on pages 111 and 112 of the March JOURNAL, would be interesting and valuable, — and the more useful because of the fact that all contractor's profit was eliminated and the work done by day labor employed directly by the Amoskeag organization.

One of the interesting features of our New England rivers, — and a characteristic of hydrology in general, — is the fact

* This paper, presented by Arthur T. Safford on January 24, 1923, was published in JOURNAL, BOSTON SOCIETY OF CIVIL ENGINEERS, Vol. X, No. 3, March, 1923.

† District Engineer, United States Geological Survey, Water Resources Branch, Boston.

that one never knows just what to expect. It is true that from records of past occurrences at Lawrence and at Lowell it is fairly easy to predict what may be expected to occur at either of those places, but it should likewise be understood that occurrences at Lawrence and Lowell do not form sufficient bases for prediction of probable occurrences as far up river as Concord and Franklin. By reference to a map of the Merrimack River drainage basin it may be seen that approximately one half the net drainage area of the Merrimack basin lies south of the latitude of Concord, N. H., and this includes the Contoocook, a large tributary heading near the Massachusetts line and provided with several storage reservoirs in Stoddard, Nelson, and Harrisville; also the Piscataquog which is likewise provided with storage reservoirs on both its north and south branches. Studies of Merrimack River hydrology indicate that the run-off from the southern half of the basin, some of it coming from south of the Massachusetts line, may not always agree with results obtained in the northern half of the basin which reaches up to the mountain slopes of Carrigan, Lafayette, and Kinsman. Conversely, with respect to the amount and distribution of run-off, the upper half, some of it standing mile high among the clouds, may not always follow the rules and regulations laid down for the lower half, much of which rests less than three hundred feet above sea level. An illustration of this is afforded by the floods of April 15-16, 1895, and March 2-3, 1896. At both Lawrence and Lowell the 1896 flood was the higher,* its ratio to the 1895 flood being as follows: Lawrence, 1.26 to 1; Lowell, 1.10 to 1. On the other hand, the records at Plymouth show that for the Pemigewasset River the conditions were reversed and the 1895 flood was the greater, its ratio to the 1896 flood being 1.09 to 1. From what data are available for the dam at Sewalls Falls, Concord, it would appear that these two floods were practically equal in height at that place, and this intermediate point lines in consistently with the variation in ratios between Lowell and Plymouth. Professor Dwight Porter incorporated in his report on "Water Power of the Merrimack River"† a number of photographs of the 1895

* See Water-Supply Paper 415, p.p. 216-217 and 242-243.

† Prepared in 1899 for the U. S. Geological Survey.

flood at Bristol* and Penacook, and at that time, 1899, the 1895 flood was undoubtedly the highest flood that had been witnessed and recorded by the residents then living in the upper Merrimack basin. However, it appears from records at Lowell† and Lawrence‡ that the flood of April, 1852, exceeded by at least ten per cent. the floods of 1895 and 1896.

It is unfortunate that we do not have more rainfall records at high elevations. The new rainfall stations at Profile, Lincoln and Waterville, referred to by Mr. Safford, are all at elevations less than one half that reached by the side walls of the basin east and west of these gages. Mt. Washington, on which precipitation records were obtained from 1871 to 1890, is sufficiently near the upper part of the Merrimack basin so that the records there are of interest, and we find that for the fifteen years during which complete records were obtained, the average annual precipitation was 83.5 inches (records for 1887 to 1890 were incomplete). The same fifteen years gave an average annual precipitation of 38.9 inches at Concord. Ought we not therefore to expect a proportionally higher run-off per sq. mi. from the upper parts of the basin? Unfortunately, the stream-flow records at Plymouth, Franklin Junction, and Garvins Falls (and possibly at other points on the river) are more or less open to attack by those who do not wish to "place dependence" on them. The grading of those records in the report of the Run-off Committee was most fair and impartial, and no attempt is now made to gloss over existing imperfections. There is, however, another source of information. During 1911 and 1912 studies of rainfall and run-off were carried on at a number of places in the White Mountain area and in the Pemigewasset River basin above Lincoln. Four gages were established on small streams tributary to the east branch of Pemigewasset River about twelve miles from Lincoln, and at three of the stations a complete twelve months' record was obtained, October 1, 1911 to September 30, 1912. Self-registering gages were used and the control sections were made

* See Report of Commission on Water Conservation and Water Power, New Hampshire, 1917-1918, Plate VIA, p. 64.

† Discharge at Lowell, April 23, 1852 was 83 000 sec. ft.; data furnished by Arthur T. Safford and published in Water-Supply Paper 415, p. 194.

‡ Discharge at Lawrence, April 23, 1852, was 94 000 sec. ft., data furnished by Richard A. Hale.

permanent by the construction of solid concrete structures designed to withstand the spring floods and at the same time be suitable for calibration. The area above each gage was measured by a special plane table survey and plotted in the field, so that careful attention was given to the physiography of each area. In sizes the areas were 6.12, 5.17, and 0.308 sq. mi., for which the measured run-offs as averaged for the year were respectively 2.61, 2.55, and 2.74 sec. ft. per sq. mi. Considering the fact that the areas were all differently located with respect to slope of area and direction of exposure, also that the forest cover was different for the several areas, varying from virgin timber to "burned over," the results appear reasonably consistent. The average of the three measurements gives a unit value of 2.63 sec. ft. per sq. mi. as the average for the twelve months ending September 30, 1912. For the same period the river gaging stations gave the following results:

Pemigewasset at Plymouth*	2.23 sec. ft. per sq. mi.
Merrimack, Franklin Jct.*	2.01 sec. ft. per sq. mi.
Merrimack, Garvins Falls*	1.76 sec. ft. per sq. mi.
Merrimack, Lawrence†	1.40 sec. ft. per sq. mi.

These points define a fairly smooth curve and show the manner in which the unit run-off in sec. ft. per sq. mi. varied with size of drainage area. The numerical results for other years would very likely differ from those given above, but there can be no reasonable doubt but that, for the Merrimack River basin, the unit run-off increases as one approaches the higher altitudes in the upper part of the basin.

* Biennial Report of the Public Service Commission of New Hampshire, 1922, p.p. 28-29.

† Water-Supply Paper 415, p. 279.

DISCUSSION.

METHODS OF DESIGN AND CONSTRUCTION, AND RESULTS OF OPERATION OF SUBMERGED PIPE LINES FOR OUTFALL SEWERS.*

LYNN PERRY.† (*By letter.*)

THE State of New Jersey has about sixty seashore resorts, most of which are provided with sewerage systems, more or less complete. Most of these have submerged outfalls, many of which are in the ocean.

Between Point Pleasant and Keyport there are, at least, twenty-nine outfall sewers, nineteen of which are ocean outfalls. Many of these serve very small municipalities, the outfalls being 8-in. or 10-in. pipes; there are, however, a few fairly large cities which dispose of their sewage by dilution into the ocean.

The State Department of Health of New Jersey prohibits the disposal of raw sewage by dilution in close proximity to a bathing beach. The method and amount of treatment depends entirely upon local conditions, each case being considered separately. For the disposal of sewage into the ocean, screening or tank treatment is usually considered satisfactory, for this removes the large solids that are likely to be driven upon the shores by strong off-shore storms. The sewage must then be carried sufficiently far from the shore to prevent its being immediately brought back by wave action.

Along the New Jersey coast, a current flows, either north or south, parallel to the beach. This current frequently comes within a few hundred feet of low-water mark. Sewage discharged from a submerged outfall into this current does not appear to cause any complaint and the disposal problem is therefore simple.

The discharge end of some of the small submerged outfalls are flush with the bottom of the ocean. The important installations, however, usually discharge into the water about eight or ten feet from the bottom to preclude the possibility of shifting

* Report of Committee of the Sanitary Section of the Boston Society of Civil Engineers, published in JOURNAL, Vol. X, No. 1, January, 1923.

† Lafayette College, Easton, Pa.

sand covering the end of the pipe. This rise at the end is usually at about forty-five degrees. A frequent design is to have the discharge end rise at 45° with the horizontal, one length of pipe; and to place on the extreme end a $\frac{1}{8}$ short-radius bend. Under this rising pipe is placed a cast-iron, wrought-iron, or steel bearing plate. This is fastened to the body of the pipe with U-bolts and to a collar near the extreme end with guy-rods. This bearing plate soon becomes covered with sand and holds the outlet end in position.

Local Health Officers and Boards of Trade have occasionally asked the State Department of Health to make special reports upon the healthfulness of this type of disposal. There is usually little cause for anxiety. An investigation of the local conditions due to an ocean outfall was made by the writer at Asbury Park,* and it was found that even during moderate northeast storms, when the surf was too rough for bathing, no pollution due to sewage could be traced to the usual bathing beaches.

Most of these submerged outfalls are of wrought-iron pipe with threaded joints. Observation indicates that the life of the pipe is somewhat less than the figures given by your committee. This is largely due to local conditions. The pipe is well protected by ample cover between the tank and low-water mark, and a failure seldom occurs between these points. During severe storms, especially when ice is present in large quantities, these pipes break beyond low-water mark. This seems to be due to a combination of three things: namely, abrasion and consequently a weakening of the pipe; shifting of the sand bars on the bottom of the ocean, which may entirely cut away the support of the pipe; and severe wave action.

Local Superintendents of Sewers are extremely efficient in replacing these submerged outfalls. The pipe is procured and the joints made with the pipe on rollers, the pipe lying perpendicular to the shore. All excavation is done and preparations made to launch the pipe. When the weather and tide are favorable, the outfall end is lashed to the stern of a power boat and the outfall pipe pulled into position. Connection to the old pipe is then made (usually with lead or cement joint) as quickly as possible and the trench backfilled.

*Eng. News-Record. September 1920, Vol. 85.

BOSTON SOCIETY OF CIVIL ENGINEERS
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PROCEEDINGS

MINUTES OF MEETINGS.

NORTHEASTERN UNIVERSITY SECTION.

BOSTON, March 28, 1923. — A meeting of the Northeastern University Section was held today at 3 p.m., in Bates Hall at the University.

Vice-Chairman Henry Brask called the meeting to order.

Mr. A. A. Northrop of Stone & Webster, Inc., delivered a very interesting lecture on "Hydro-Electric Plants" built by his firm on the Pacific Coast. The lecture was fully illustrated by motion pictures.

Members and visitors present about 300.

A. O. BRADSHAW, *Clerk.*

DESIGNERS SECTION.

BOSTON, April 11, 1923. — The regular April meeting of the Designers Section was called to order in the Affiliation Rooms at 6.10 p.m. by Chairman Walter W. Clifford.

The report of the March meeting was read and approved.

The Chairman introduced Howard M. Turner, Consulting Engineer, of Boston, who spoke upon "Structural Details of Water Power Plants."

Mr. Turner described details of dams, gates, stop logs, screens, scroll cases, etc.

An open discussion followed the talk. There were 43 members and visitors present.

The meeting adjourned at 8 P.M.

WALDO F. PIKE, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[May 15, 1923.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

For Admission.

AVERELL, EDWARD SPINNEY, Lynnfield, Mass. (Age 23, b. Lynn, Mass.) Student at Mass. Institute Technology, Senior year. Refers to J. B. Babcock, C. B. Breed, K. C. Reynolds and Hale Sutherland.

HAMILTON, EDWARD PIERCE, Milton, Mass. (Age 26, b. Newtonville, Mass.) Educated at Milton Academy, Harvard College and Harvard Engineering School. Was in Artillery School 1918, and 2nd Lieut. 350th F. A., U. S. A. 1918-19. From 1920 to date has been assistant on the engineering

staff of the Proprietors of Locks and Canals, Lowell, Mass.; also has worked at various times on hydraulic work for A. T. Safford. Refers to R. A. Hale, H. J. Hughes, S. S. Kent, A. T. Safford and H. M. Turner.

MITCHELL, FRANCIS H., Lawrence, Mass. (Age 37, b. Lowell, Mass.) Educated in the public schools of Lowell and later took a complete course in the I. C. S. From 1904-6 was assistant to O. M. Snell, civil engineer of Lowell; 1906 to the present time has been in the employ of the Essex Water Power Co., in general computation on hydraulic matters, etc. Refers to J. R. Baldwin, R. A. Hale, C. H. Rooks and A. T. Safford.

RICE, PERCIVAL S., Dorchester, Mass. (Age 20, b. Dorchester, Mass.) He is a student at Mass. Institute of Technology, class of 1923. Refers to J. B. Babcock, C. B. Breed, K. C. Reynolds, A. G. Robbins, C. M. Spofford and H. Sutherland.

ROBBINS, JAMES MELVIN, Belmont, Mass. (Age 21, b. West Newton, Mass.) From October, 1919 to date a student at Mass. Institute of Technology in civil engineering department. Refers to J. B. Babcock, C. B. Breed, J. W. Howard, K. C. Reynolds, C. M. Spofford and Hale Sutherland.

SAFFORD, TRUMAN HENRY, Lowell, Mass. (Age 28, b. Lowell, Mass.) Graduate of Williams College 1917, and two years at Harvard Engineering School. Summers of 1913-14-15 employed by Proprietors of Locks and Canals and A. T. Safford, as rodman and draftsman; summer of 1917 with Turners Falls Power and Electric Co., as rodman on construction of Hampden Steam Station; Sept., 1917-May, 1918 chemist on Gas Defense Research; May, 1918-Jan., 1919, U. S. Army Machine Gun Section; June, 1919-Jan., 1923, partner in Turner, Millspaugh & Safford, Boston, on hydraulic problems; Jan., 1923 to date, assistant to Arthur T. Safford, Cons. Engr. Refers to J. R. Freeman, R. A. Hale, H. J. Hughes, S. S. Kent, C. W. Sherman and H. M. Turner.

TITCOMB, ALBERT CLEMENT, Boston, Mass. (Age 38, b. Salem, Mass.) Graduate of Harvard College 1907. Since that date he has been connected with the New England Foundation Co., Boston, of which he is now president and treasurer. Refers to H. S. French, J. A. Garrod, F. M. Gunby, J. F. Osborn, H. E. Sawtell and J. R. Worcester.

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LIBRARY NOTES.

BOOK REVIEW.

"SHIELD AND COMPRESSED AIR TUNNELING." By B. H. M. Hewett, M. Am. Soc. C. E., M. Inst. C. E.; and S. Johannesson, M. Am. Soc. C. E. First edition. McGraw-Hill Book Company, Inc. 1922.

REVIEWED BY LEONARD LEE STREET.

From a practical and theoretical point of view, this book is a most complete treatise on shield tunneling, and is one that all engineers and contractors ought to read.

The first few chapters dealing with tunnel methods are followed by a chapter on the history of tunnels, with a list of all shield-driven tunnels in America and abroad.

A Bostonian reading this list, immediately wonders why there is no mention of the shield-driven, two-track tunnel constructed by the Boston Elevated under Massachusetts Avenue, Cambridge, extending from Central Square, towards Harvard Square, also the tunnel under State Street from Atlantic Avenue west.

The chapters on tunnel linings and shields, plant and equipment, both in tunnel and on surface, together with the chapters on methods of construction, ought to be carefully studied by all contractors who are engaged in this class of work.

The author, in the chapter on Practical Matters of Design, states that, "Driving around a Curve greatly increases the cost of construction." Our experience in Boston does not bear out this statement. The two single-track tunnels under the Fort Point Channel, include sections built on a curve of about five-hundred (500)-foot radius, with a length of arc five hundred and fourteen (514) feet; also the East Boston Tunnel was built on a curve of two thousand (2 000)-foot radius, with a length of arc of fourteen hundred and eighty-eight (1 488) feet, and in both cases the cost of construction was not increased or the progress diminished.

The book ends with a chapter on compressed air illness, written for engineers by engineers, on the cause and symptoms of the disease, together with the necessary precautions that should

be taken in going through the locks. This chapter is very instructive and is a fitting closing to an admirable book on shield tunneling.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Report of Chief of Weather Bureau. 1921-22.

State Reports.

Massachusetts. Report of Statistics of Manufactures. 1920.

Municipal Reports.

Boston, Mass. Report of Public Works Dept. 1921.

Boston, Mass. Report of Transit Dept. 1921.

Brookline, Mass. Report of Town Engineer. 1922.

Detroit, Mich. Metered Water Rates. January, 1923.

New Bedford, Mass. Report of Water Board. 1922.

New York, N. Y. Contract 198. Narrows Siphon No. 2, Catskill Aqueduct.

Northampton, Mass. Report of Water Commissioners. 1922.

Peterborough, N. H. Report of Public Works Dept. 1922.

Springfield, Mass. Report of Municipal Water Works. 1922.

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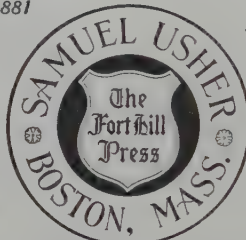
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